

III-V-on-silicon Photonic Integrated Circuits for Spectroscopic Sensing in the Mid-Infrared

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Abstract: We present an overview of our work on mid-infrared photonic integrated circuits comprising silicon photonic ICs for the passive functionality and heterogeneously integrated III-V semiconductor devices for light generation and detection.

OCIS codes: (130.7408) Wavelength filtering devices; (130.3120) Integrated optics devices; (130.3060) Infrared

1. Summary

III-V/silicon photonic integrated circuits (ICs) promise to enable low cost and miniature optical sensors for trace-gas detection, bio-sensing and environmental monitoring. A lot of these applications can benefit from the availability of photonic ICs beyond the telecommunication wavelength range. Silicon-on-insulator (SOI) waveguide circuits allow operation up to about 4 μm wavelength. Combined with suitable III-V semiconductors (InP type-II active regions or GaSb-based opto-electronic components) highly integrated systems-on-a-chip in the 2-4 μm wavelength range can be realized. Beyond 4 μm wavelength alternative CMOS-compatible waveguide platforms need to be considered, such as germanium-on-SOI. In this paper we will present 2 μm -wavelength-range III-V/silicon photonic ICs consisting of tunable laser sources, photodetectors and silicon waveguide circuits. Active opto-electronic components are integrated on the photonic IC by the heterogeneous integration of an InP-based type-II epitaxial layer stack on silicon. III-V-on-silicon 2.3 μm range distributed feedback (DFB) lasers operate up to 25 °C in continuous-wave regime and shows an output power of 3 mW. By varying the silicon grating pitch, a DFB laser array with broad wavelength coverage from 2.28 μm to 2.43 μm is achieved [1]. III-V-on-silicon photodetectors with the same epitaxial layer stack exhibit a responsivity of 1.6 A/W near 2.35 μm . Integrated spectrometers based on silicon arrayed waveguide gratings and integrated photodetector arrays [2] and single pixel detectors [3] are demonstrated. In addition, we also report a 2 μm range GaSb/silicon hybrid external cavity laser using a silicon photonic IC for wavelength selective feedback. A wavelength tuning over 58 nm and side mode suppression ratio better than 60 dB is demonstrated [4]. For the 3 μm wavelength we demonstrate the realization of high-performance arrayed waveguide gratings [5] and integrated spectrometers based on GaSb-based p-i-n photodetectors heterogeneously integrated on the silicon waveguide platform [6]. Beyond 4 μm wavelength we propose the use of germanium on silicon-on-insulator waveguide circuits. We demonstrate high efficiency grating couplers [7], thermo-optic heaters [8] and widely tunable Vernier ring resonator filters [9] on this platform in the 5 μm wavelength range. Such circuits can then be integrated with III-V semiconductor quantum cascade or interband cascade gain chips to realize miniaturized widely tunable lasers.

2. References

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